ohmic heating treatment of fruit puree

pilot scale ohmic heating treatment of fruit puree containing particles – influence of the processing temperature on quality parameters

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Abstract

Ohmic heating is an alternative pasteurization process and is growing interest in industry. Understanding the influence of ohmic heating on the sensorial and microbiological quality of foods is a pertinent matter. This study concerns with the pasteurization effects of a pilot scale continuous ohmic heater on a strawberry puree containing fruit particles on relevant quality parameters of the product. The impact of pasteurization temperature (85 ºC, 90 ºC, 95 ºC) on the microbiological load, size distribution of strawberry particles (<0.3 g, 0.3 g to 0.7 g, 0.7 g to 1 g and >1 g), texture and microbial stability was studied. All treatments destroyed yeasts and moulds to values below 10 CFU/mL. The strawberry particles size distribution shows that the average size of particles decreased with increasing treatment temperature. A texture reduction, measured in terms of the force applied on a 5-blade Kramer cell, was observed when strawberry particles were collected before and after the thermal treatment: 20 %, 23 % and 25 % reduction at 85 ºC, 90 ºC and 95 ºC, respectively. The reduction for a scrapped surface heat-exchanger treatment at 95 ºC was of 31 %. In conclusion, ohmic heating reduces the product microbiological load and for parameters such as texture and size distribution of the strawberry particles the cooking effects are reduced when compared with a scrapped surface heat-exchanger treatment.

Resumo

Ao longo das últimas décadas o aquecimento óhmico tem vindo a ganhar interesse por parte da indústria. Assim, torna-se necessário compreender a influência do aquecimento óhmico nas propriedades sensoriais e microbiológicas dos alimentos. O principal objectivo deste trabalho é a análise dos efeitos de pasteurização contínua realizada num aquecedor óhmico à escala piloto. Foram estudados os efeitos de diferentes temperaturas de pasteurização (85 ºC, 90 ºC, 95 ºC) na carga microbiana, na integridade dos pedaços de morango, na textura e na estabilidade microbiana. Todos os tratamentos efectuados reduzem os valores de fungos e leveduras para valores inferiores a 10 UFC/mL. A análise da integridade dos pedaços de morango revelou que o tamanho médio dos pedaços diminui com o aumento da temperatura de tratamento. Foi também detectada uma redução da textura, medida em termos de força aplicada numa célula de Kramer de 5 lâminas, em relação à textura dos pedaços antes do tratamento: esta diminuiu 20 %, 23 % e 25 % para os tratamentos a 85 ºC, 90 ºC e 95 ºC, respectivamente. Esta redução foi ainda superior (31 %) para as amostras submetidas ao tratamento realizado num permutador de superfície raspada a 95 ºC. Com a realização deste trabalho foi possível concluir que utilizando a tecnologia de aquecimento óhmico é possível reduzir a carga microbiana e que os efeitos de cozedura excessiva são atenuados quando comparado com um tratamento efectuado num permutador de superfície raspada.

1. INTRODUCTION

To extend shelf life of food products a heat treatment is generally required. This may be provided through the use of e.g. tubular heat exchangers or scraped surface devices, where heat is generated outside the food and transmitted to it by conduction and/or convection. For products containing particles, like fruit, the mentioned heat treatments frequently cause overheating of the liquid if sufficient heating of the solids is to be achieved, leading to a loss of nutritional as well as organoleptic characteristics.

In aseptic processing of two-phase food systems, ohmic heating of food products is seen has a potential alternative to conventional heating processes because, for the former, in many situations particles heat as fast or even faster than liquid [1], [2].

Ohmic heating (or Joule heating) is defined as a process where electric current is passed through foods to heat them. The principal advantage of ohmic heating is the ability to heat materials rapidly and uniformly: the overprocessing of the foods is prevented, avoiding further destruction of nutrients and flavour compounds, leading to a higher quality product, both from the nutritional and organoleptic points of view.

Ohmic heating technology has been known since the 19th century when several processes which used electrical energy for heating flowable materials were patented [3]. This technology was extensively used to pasteurize milk, and by 1938, almost 50000 citizens were consuming milk pasteurized by ohmic heating in the U.S.A. [4], [5]. However, the use (and research) on this technology was abandoned due to high processing costs [6] and lack of inert materials for the electrodes production, apart from electroconductive thawing [7].

More recently, ohmic heating technology has gained further interest because the products obtained are of superior quality (including extended shelf-life) to those processed by conventional technologies [4],[5],[8–11].

Thermal processing of fruit purees is traditionally difficult, essentially due to their rheological properties. The problem is aggravated when fruit particles are present in the slurry, as in the case of fruit purees to be incorporated in yoghurts. The use of conventional heat exchangers is not possible and scraped surface devices are normally used, instead. The contact of the slurry with a hot surface is promoted and mixing is achieved by means of rotating blades. These are responsible for mechanical damage to the fruit particles affecting the final quality of the product and diminishing its acceptability to the consumer.

Several factors affect the heating rate of foods subjected to ohmic heating such as the product electrical conductivity, specific heat and the particles properties – size, shape and concentration as well as the particle orientation in the electric field. In particular, understanding the influence of the temperature and electrical conductivity for the sensory and microbiological quality of the final product is very important [12].

Palaniappan and Sastry (1991) [13] studied the effects of insoluble solids and applied voltage on electrical conductivity of the pre-pasteurized carrot and tomato juices, during ohmic heating. Those authors also investigated the effect of applying a higher voltage gradient of 60 V/cm to potatos, and carrots [14]. Castro et al (2003) [15] studied the effect of temperature and sugar content on the electrical conductivity values of strawberry based products. All of mentioned works concluded that ohmic heating can be advantageously used to process very diverse types of foods (e.g., ohmic heating is even being used for processing entire fruits [16]).

Icier and Ilicali (2005) [17] discussed the temperature dependence of the electrical conductivities of apricot and peach purees during ohmic heating. They have concluded that the electrical conductivity of the fruit purees is strongly dependent on temperature, ionic concentration and pulp content.

Praporscic et al (2006) [18] studied the effect of ohmic heating on juice yield from potato and apple tissues. They showed that the tissue disintegration degree and juice yield depend on the electric field intensity, temperature, treatment duration and type of plant tissue.

None of these works, however, have been performed at pilot scale. In fact, very seldom research has been conducted at pilot scale [19–21]. The main purpose of this work is to evaluate the effects of continuous ohmic heating pasteurization at pilot scale, on relevant parameters of strawberry puree (containing fruit particles) quality.

2. MATERIALS AND METHODS

2.1. System description

The continuous ohmic heater pilot plant used in the experiments is represented in Figure 1. The strawberry puree was heated in the ohmic heating column and it was maintained in a holding section for 210 s (equivalent flow of 300 kg/h). Cooling was achieved in a tubular heat exchanger with a flow of cold water (at 4 °C) and the product was recovered at approximately 33 °C in an aseptic tank. From this tank, the product was finally placed in 5 L sterile Bag in Box packages.

2.2. Strawberry puree preparation

The strawberry puree was prepared in batches of 250 kg containing in its composition essentially 70 % (w/w) of strawberry and 20 % (w/w) of sucrose, according to the formulation given by Frulact S.A.. The ingredients were added sequentially in a heated vessel and mixed during 15 min to 20 min, at 35 °C, to improve the homogeneity of the temperature and the electrical conductivity. At this stage, the strawberry puree was ready for pasteurization.

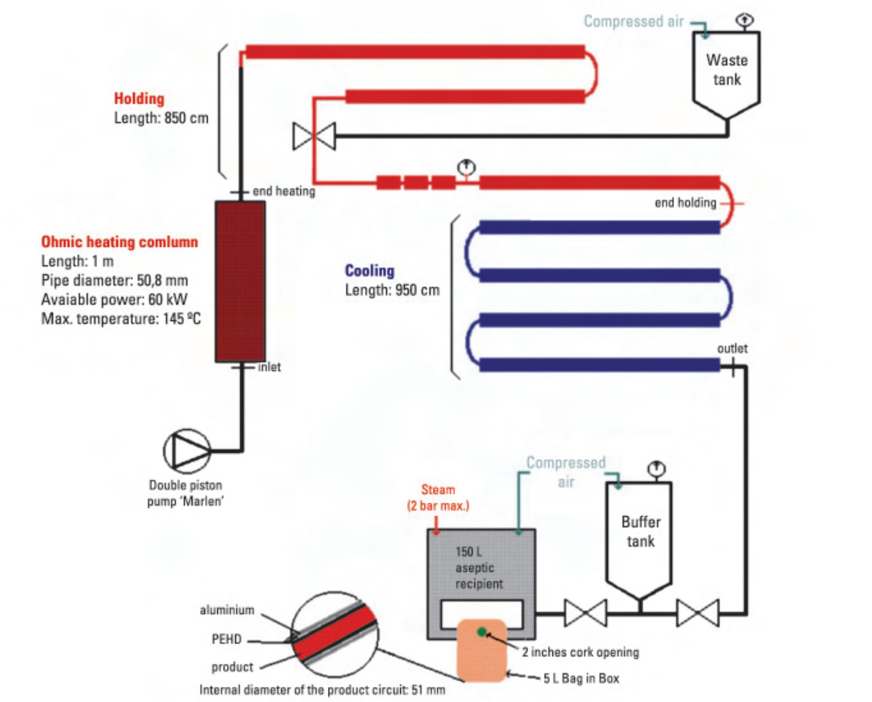

Figure 1 Continuous ohmic heating pilot plant, including the holding and cooling sections, as well as the aseptic packaging unit.

2.3. Study of the effects of the intensity of the thermal treatment

The goal of this study was to evaluate the effect of the thermal treatment temperature (and consequently the heat treatment intensity, since the holding time is constant – 210 s with 300 kg/h flow) on relevant parameters of the strawberry puree: microbiological load, amount of restrained solids, texture and microbial stability. The tests were carried out starting from the higher temperature to the lower (95 °C, 90 °C and 85°C). This procedure was adopted, so that a product treated at a lower temperature does not contaminate a product treated at a higher temperature, when cooling takes place.

2.4. Analytical procedures

2.4.1. Strawberry puree electrical conductivity

The critical parameter of an ohmic heating treatment is the electrical conductivity of the tested product. This one was measured as described in Castro et al (2004) [22] for both the strawberry dices: before being incorporated and after being incorporated in the mixture itself. To determine the electrical conductivity of the fruit dices already mixed in the product, care was taken to wash the particles with water to avoid influences from the surrounding medium.

2.4.2. Microbiological analyses

Two samples of the product were analyzed for each test, regarding the total flora, yeasts and moulds, before and after the thermal treatment. The total count (CFU/mL) was made according to the Portuguese standard NP 4405 (2002) [23]. The samples were collected in sterilized jars and homogenized in aseptic conditions.

The spore count in the samples with thermal treatment was performed after the application of a selective treatment to the samples (100 °C for 10 minutes); this procedure allowed the survival of the spores, only, being the samples counted in Petri dishes containing nutrient agar after growth at 30 °C.

2.4.3. Determination of the amount of restrained solids

The possible effect of the thermal treatment intensity on the preservation of the integrity of the fruit particles has been determined by the evaluation of the amount of restrained solids. This is extremely important as a quality parameter for the customers and significantly influences the products selling price. The amount of restrained solids was assessed in 500 g samples of product, collected in three points on the retention tank of finished product. This procedure was adopted since concentration gradient was observed in the tank, even in the presence of mixing. These samples were forced by a water current through three consecutives shaking sieves of decreasing net sizes (7.1 mm, 4.0 mm and 1.0 mm respectively) during 4 min. The water current was on only during the first two minutes. Finally, the mass of restrained solids (fruit dices) in each sieve was weighted. The initial mass of each sample was previously weighted. This procedure was repeated in triplicate for each sampling point.

2.4.4. Texture analyses

Textural qualities were measured to evaluate the effects of the treatments on the product structure. This information will complement the one obtained with the evaluation of the amount of restrained solids. The analyzed strawberry particles have been removed from samples of finished product, washed and drained before the analysis. The texture was determined using a Texture Analyzer (TA-XT2, Stable Micro Systems, UK). It was used a 5 blade Kramer cell with a compression load cell of 5 kg. Each experiment was conducted with 200 g of strawberry particles. Four replicates were made for each determination. The texture was reported as peak force and expressed in grams and the results were compared to those obtained for a similar product, made with the same lot of fruits, in a conventional processing line with a scrapped surface heat exchanger.

2.4.5. Analyses of the microbial stability of the product

Three bags of each treatment were randomly selected to analyze the microbial stability of the product.. Two of those were stored at 37 °C and one bag was stored at 4 °C for 7 days. At the end of the incubation period, the growth of microbial flora was examined by immersion microscopy and the pH was also measured, according to the standard NF V08-408 (France).

3. RESULTS AND DISCUSSION

3.1. Electrical conductivity

The value of this important property was determined both for strawberry dices, and for the product before the heat treatment. In the product, the conductivities of the fruit dices (0,3 S/m at 25 °C) and of the surrounding liquid phase (0,3 S/m at 25 °C) were obtained separately. This allowed the comparison of the values of conductivity for the fruit alone (0,4 S/m at 25 °C), and when mixed with the other ingredients (0,3 S/m at 25 °C).

The most important conclusion to be drowned from these results is that the value of the electrical conductivity is the same for the solid (dices) and liquid phases of the product. This is extremely important when processing such products by ohmic heating because it guarantees uniform heating and minimizes temperature differences inside the product.

The fact that the strawberry dices showed a conductivity value of 0,4 S/m before being mixed with the other ingredients and only 0,3 S/m when that mixture was performed is well documented in the literature [22] and it is known that non-electrolytes such as sucrose reduce the conductivity by reducing ion mobility.

3.2. Study of the effects of the intensity of the thermal treatment

3.2.1. Thermal treatments applied

The Figure 2 presents the product temperature evolution during the heat treatment carried out at 85 °C. For the others treatment conditions, the temperature evolutions were comparable, but of course, at a higher temperature.

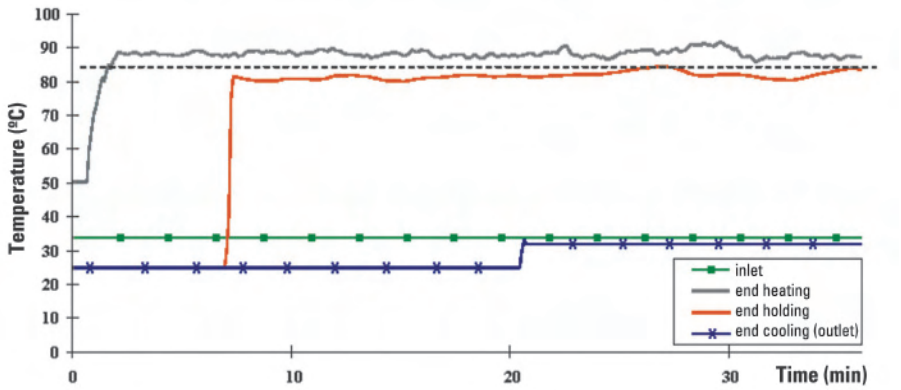

Figure 2 Temperature evolution at the *inlet* (installation entrance), *end heating* (exit of the ohmic heating column), *end holding* (exit of the holding section) and *end cooling* (exit of the cooling section) during the test time at 85 ºC.

The product temperature at the entrance (inlet) of the pilot installation was 33.8 °C.

After a quick increase of the product temperature at the ohmic column exit (end heating), an ohmic heating characteristic, a progressive temperature rise is noted (process control parameters are readjusted) until the setpoint temperature of 85 °C is achieved. After temperature stabilization, the product enters in the holding section.

During all the test time, there were temperature variations at the ohmic column exit, of ± 3 °C around 85 °C, with few minutes periods where the variation is lower than ± 1 °C. These small temperature variations were attenuated on the tests at 90 °C and 95 °C. When the heat treatment was stopped, the temperature in the pipes drops very quickly, showing that there was a negligible heat accumulation in the equipment.

The end holding temperature increased very quickly because of the sudden arrival of product which was at the ohmic column exit temperature (Figure 2). During the test at 85 °C, the holding exit temperature, measured 3.5 minutes after the heating, was 81 °C on average. This value is very stable during the tests since the instantaneous temperature variations, measured at the exit of the ohmic column, are attenuated by the mixture of the product in the holding pipe (presence of elbows and other elements that create turbulences).

The product temperature at the end of the cooling section was approximately 33 °C. Table 1 presents the parameters and variables obtained during the tests at different temperatures.

	95 ºC	90 ºC	85 ºC
Instantaneous consumed power (kW)	19.2	16.4	15.4
Intel temperature (ºC)	36.5	42	33.8
Edn heating temperature (ºC)	96	91.7	86.5
End holding temperature (ºC)	93	87.7	81.1
End cooling (outlet) temperature (ºC)	34.7	32.9	32.7
Minimal F70 ºC (min)	700	207	45
Tension (V)	3000	3000	3000
Imax (A)	190	170	140
Apparent cp (kcal/(kJ.K))	0.965	0.998	0.883

Table 1 Parameters and variables obtained during thermal treatments at 85 ºC, 90 ºC and 95 ºC using a flow rate of 300 kg/h.

	85 ºC				90 ºC				95 ºC			
	Before treatment		After treatment		Before treatment		After treatment		Before treatment		After treatment	
	1	2	1	2	1	2	1	2	1	2	1	2
Total flora	3400	2600	1300	500	3400	2600	1300	500	3400	2600	1300	500
Yeasts	140	130	<10	<10	140	130	<10	<10	140	130	<10	<10
Moulds	10	10	<10	<10	10	10	<10	<10	10	10	<10	<10

Table 2 Results of the total flora, yeasts and moulds analyses (*CFU/mL*) after thermal treatments at 85 ºC, 90 ºC and 95 ºC with the same holding time (210 s).

	85 ºC	90 ºC	95 ºC
Mesophile aerobic spores	<10	<10	<10
Thermophile aerobic sopres	<10	<10	<10
Mesophile anaerobic spores	7	<3	<3
Thermophile anaerobic sopres	<3	<3	<3

Table 3 Results of the spores present after after thermal treatments at 85 ºC, 90 ºC and 95 ºC with the same holding time (210 s).

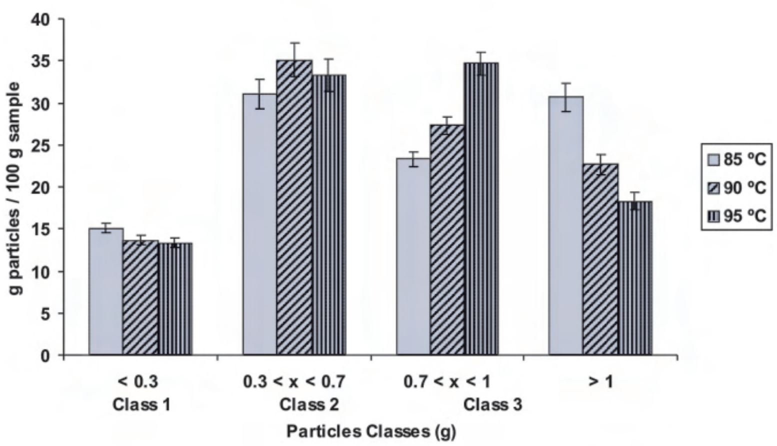

Figure 3 Mass yield (g particles/100 g sample) of strawberry dices obtained after thermal treatments at 85 ºC, 90 ºC and 95 ºC, in function of the particles medium sizes (*x*).

3.2.2. Microbiological analyses

All the heat treatments destroy yeasts and moulds. On the other hand, the total flora was differently altered, according to the treatment intensity. The treatment at 85 °C apparently showed a less pronounced effect on the residual total flora measured, while the higher temperature treatments generate a decimal reduction in the CFU number per mL (Table 2).

The results in Table 2 show that only a group of spores survived in the sample taken at 85 °C. For the samples corresponding to other processing temperatures, where the intensity of the treatment was higher, the amount of spores in the product was lower than the detention limit of the analytical technique used. This confirms the conclusions drawn from the results in Table 2, and gives a clear indication of the minimal temperature needed for an adequate processing.

3.2.3. Determination of the amount of restrained solids

Four classes of particles were defined: Class 1 (mass inferior to 0.3 g), Class 2 (mass between 0.3 g and 0.7 g), Class 3 (mass between 0.7 g and 1.0 g) and Class 4 (mass equal to or higher than 1.0 g). In order to avoid the effect of different samples' sizes, the results in Figure 3 were represented in terms of the mass of particles in each class divided by the total mass particles in the sample in question.

Class 1 and Class 2 particles are represented in similar relative amounts for the three thermal treatments. The amount of this type of particles in the product is usually connected with the preparation of the product and with its circulation through the piping, which was unchanged in the different experiments. This justifies the fact that the differences between the results of the thermal treatments were not significant. On the other hand, it was possible to observe significant differences between treatments in the amount of Class 3 and Class 4 particles; the former decrease and the later increase when the treatment intensity decreases.

3.2.4. Texture analyses

The texture variations after the ohmic treatments and after a conventional treatment at 95 °C are presented in Figure 4. The effect of the thermal treatment was evident. There was a significant reduction of the applied force (and therefore of the rigidity of the fruit dices), between dices collected before and after the thermal treatment. It was also evident that the dices' texture is related with the intensity of the thermal treatment used. The differences were not very significant under a strict statistical point of view, but it was possible to notice a reduction of the dices average resistance to the crushing by the texturemeter with increase of the intensity of the treatment. Such difference is more pronounced for the samples obtained in a conventional processing line with a scrapped surface heat exchanger at 95 °C.

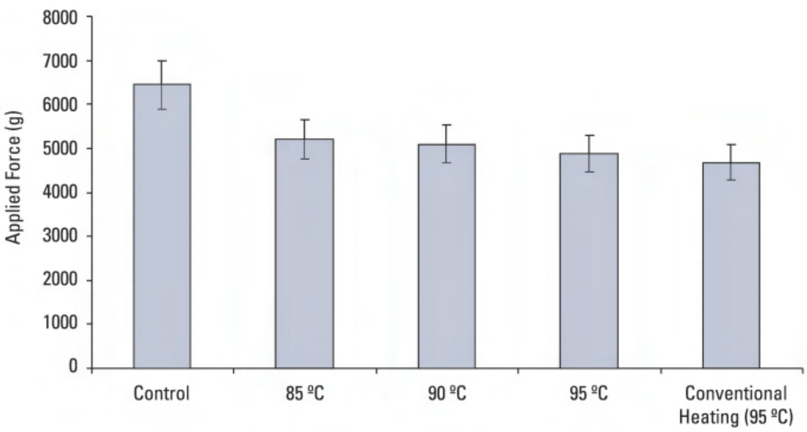

Figure 4 Average texture of the samples evaluated before (control), after ohmic treatments at 85 ºC, 90 ºC, 95 ºC and after conventional treatment at 95 ºC.

These results confirm the previous conclusions of the experiences of restrained solids distribution size: the more intense the thermal treatment is, the weaker the texture becomes and therefore there is a reduction of the particle size during the product circulation in the production line.

3.2.5. Analyses of the microbial stability of the product

The microscopic examinations did not reveal any microbial development on the samples at the end of storage time. After seven days storage, the pH did not present significant variations, remaining at 3.8 ± 0.8 for all treatment conditions. These results were obtained for a 7 days storage period, at two different temperatures (4 °C and 37 °C), confirming the absence of microbial activity.

4. CONCLUSION

As any other heat treatment, ohmic heating reduces the product microbiological load in order to allow storage for a reasonable time without product alteration. The main difference is that it allows a very fast heating (< 30 s) making it possible to limit the cooking effects when compared with a treatment in a scrapped surface heat-exchanger. One of the main consequences of this is that the number of technical stops for maintenance is very significantly reduced for cleaning operations. This work has also concluded that there is a significant reduction of the integrity of the fruit particles when comparing dices collected before and after the ohmic treatment. However, such differences are even more pronounced for the fruit puree treated by conventional treatment. Moreover, ohmic heating reduces the product microbiological load and for parameters such as texture and size distribution of the strawberry particles the cooking effects are reduced when compared with a scrapped surface heat-exchanger treatment.

This technology has shown a high potential for thermal treatment of fruit formulations.

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